

Implementation of a Gravity Compensating Mirror on a Large Aperture Antenna

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ABSTRACT

Introduction

At the NASA Deep Space Network (DSN) Goldstone Complex, located in the Mojave Desert in California, a 34-meter-diameter beam waveguide (BWG) antenna, 1)SS- 13, has become an integral part of an advanced systems program and a test bed for technologies being developed to introduce Ka-band (32 GHz) frequencies into the DSN. The antenna efficiency at 34 GHz was found to depend significantly on the elevation angle, i.e., it decreased from 45% to 35% as the elevation angle changed from 45 degrees to 20 degrees. This elevation angle dependence is due to the deformation of the main reflector caused by the resulting change in gravitational force applied to the antenna structure.

A proposed technique for compensating gravity - induced structural deformations is to utilize a deformable flat plate (DFP) installed at one of the mirror locations in the beam waveguide optics. An initial low cost demonstration of the technique was performed at 1)SS-13 using a fixed elevation angle and a manually adjustable DFP. The RMS was improved from 0.59 mm for the initial no-correction flat plate to 0.49 mm for the initial analytically derived correcting surface and, finally, to 0.36 mm for the holography-derived DFP. This would represent an improvement of approximately 2.0 dB at 32 GHz. This problem of elevation angle efficiency dependence also occurs at the NASA 70-meter antenna. Because of the larger structure, the efficiency dependence is even greater going from 35% at the 45-degree rigging angle to 15% at 20 degrees. As a solution for both systems, a fully actuated DFP is being designed and built. The same plate will be tested in both the 34-meter and 70-meter antennas. Improvements of 1-2 dB is expected for the 34-meter antenna and more than 3 dB at low and high elevation angles for the 70-meter antenna.

Approach

The approach taken was to thoroughly test the components and assembly procedures of the planned DFP with a two-actuator fixture to verify performance and minimize risk prior to installing the fully actuated plate on the antenna. The testing was done in parallel with the analysis to determine optimal actuator placement and stroke while minimizing the number of actuators required.

Analysis

The actuator placement is determined using a simulated annealing algorithm which can provide near optimal results with minimal computational time. As each new actuator configuration is evaluated within the optimization routine, the stiffness matrix is altered. To

minimize computational time, the structure stiffness is partitioned according to possible actuator locations and the remaining structure. By using static condensation on the partitioned matrix, only a small subset of the full stiffness matrix undergoes repeated inversion during the iterative optimization procedure,

in addition to determining the actuator placement, analytical efforts are continuing to verify the FEM response is consistent with the measurements. Of particular interest is the modeling near the actuator attachment points, boundary conditions, and true displacement behavior of the actuators.

Hardware Requirements and Selection

The design criteria for the hardware selected are that it must meet the contour requirements, be reliable, and be cost effective. A test program has been implemented to assure the first two requirements. Use of proven, off the shelf components further supports the last two requirements. A two station (two actuators) device is used for initial testing because it is easier to change the set-up, provides the necessary data, and in the event of a failure offers less financial exposure to the program than does testing on the final fifteen station device,

The actuator chosen consists of an AC stepper motor, driving a JPL designed double screw-thread final stage through a gearhead reduction. The double screw thread final output supports the reflective surface and reacts side loads without putting the motor output shaft in bending, which could cause the motor to stall,

The mirror surface selection is based on the deformation requirements as well as RF (radio frequency) considerations. The material properties and sheet thickness are chosen to avoid a "tent pole" effect around the actuators while minimizing the axial and lateral forces on the actuators.

The actuator attachments to the plate are limited to methods that would not introduce any discontinuities on the front surface of the plate which would degrade the RF performance. Adhesive bonding was selected to reduce surface deformation that can be generated by welding. The adhesive bonding process was approached cautiously since an earlier experiment had unexplained bonding failures.

Preliminary Test Results

Preliminary tests have been performed to determine: (1) the appropriate adhesive bonding area and bonding strength, (2) evaluate the expected cycle life, and (3) verify expected force-displacement relationships on the actuator deformed panel,

The initial test performed was the adhesive test using HYSOL 9309.3NA. A major concern was the peel strength of the adhesive. We wanted the slope on the pull specimen panel around the bond area to approximate the expected slope on the actual panel to ensure we had the same peel component. As the test panel frame was small, a thinner material was used to approach the same slope by having greater deflection. Completed test results showed we could obtain #265 pounds

strength in the worst case.

The two station device was assembled to verify predicted force-displacement relationships. Dial indicators were installed to measure panel deflections, and load cells were attached to both studs to measure the applied force. Force-deflection curves were obtained for two plate thicknesses, .030 and .040 inch and compared to preliminary analytical results which showed agreement to within 100/O.

The next test was the fatigue test using a .040 inch plate in the two station device to simulate the expected motion for an actuator during a ten year period. With one actuator disengaged, the other was operated for 15,000 cycles at a displacement of $\pm .040$ inch. This process was repeated using the other actuator for 15,000 cycles $\pm .100$ inch. No problems were encountered during these tests.

Future Work

The results from the two station device indicate that the components selected to assemble the 34-meter antenna DFP are reliable and cost effective. The assembly for the antenna is expected to have a maximum of 15 actuators and to achieve one contour or a family of contours if necessary. Future efforts will be directed toward finalizing actuator placement, fabricating the 15 station device, and correlating the predicted and measured flat plate contours. Once the 15 station device is operating successfully, antenna performance measurements will be made to assess the DFP contribution. Upon completion, effort will be directed toward installing a DFP on the 70-meter antenna.